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(54) PRODUCTION METHOD FOR OPTICAL DEVICES

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CPC ***G02B 6/3652*** (2013.01); ***G02B 6/30*** (2013.01)

(57) **ABSTRACT**

A method includes: an optical component installation process P1 in which an optical component **23** is formed on one face of a component installation substrate **10** using a thin film process, the optical component **23** having an end portion **25** to be optically coupled to an optical fiber **40**; an optical fiber fixing process P2 in which a V-shaped groove **35** is formed on one face of an optical fiber fixing substrate **30** and the optical fiber **40** is fixed to the V-shaped groove **35**; and a contacting process P3 in which the surface of the component installation substrate **10** on which the optical component **23** is provided is contacted with the surface of the optical fiber fixing substrate **30** to which the optical fiber **40** is fixed.

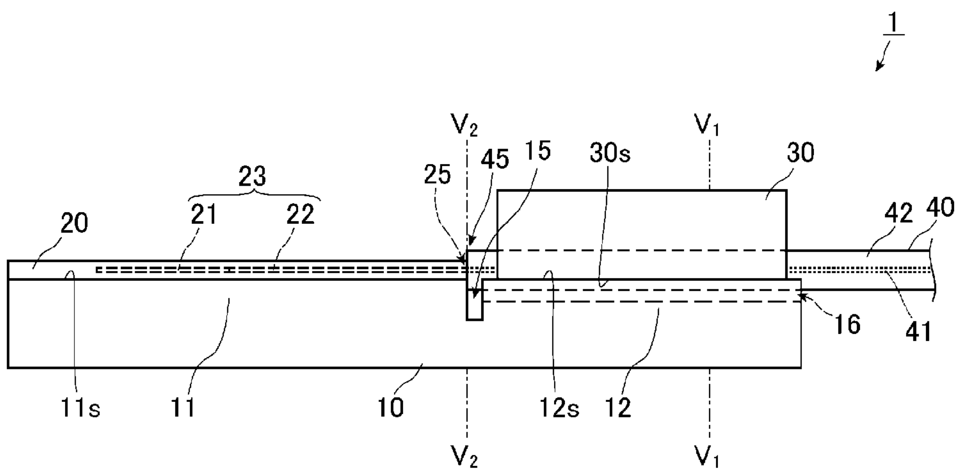


FIG. 1

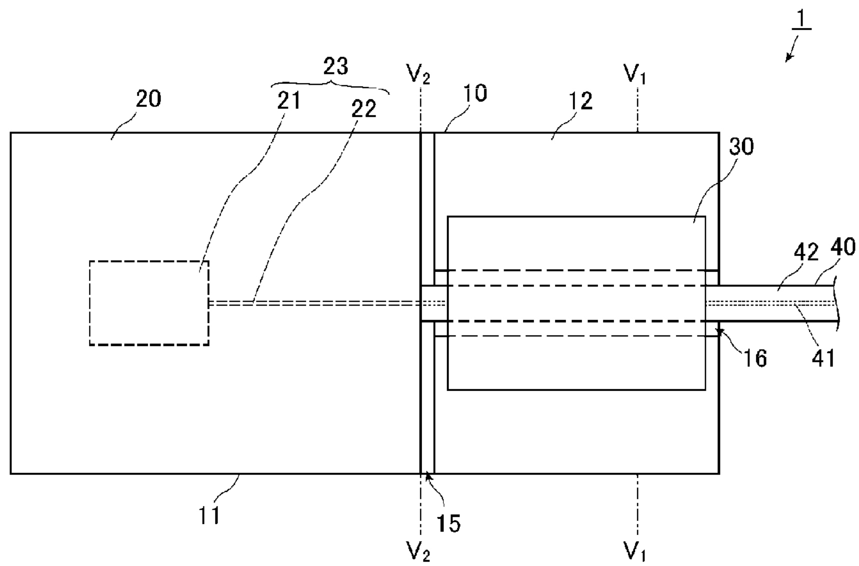

1
23
21
22
20
V2
10
12
V1
30
42
40
16
41
11
15
V2
V1

FIG. 2

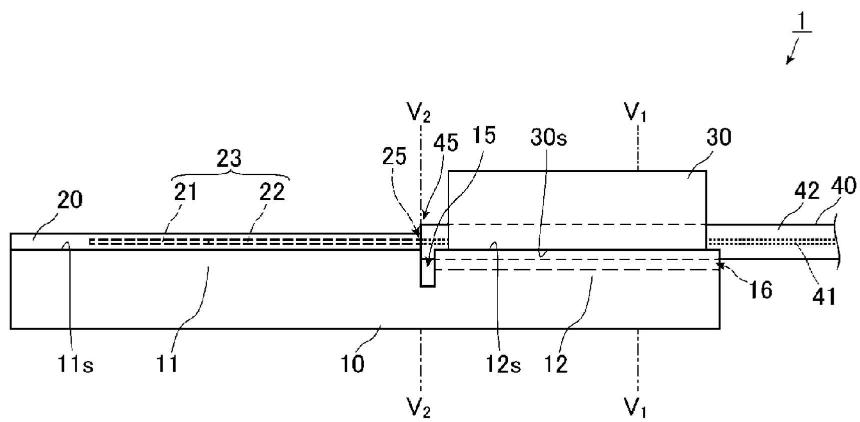

1
V2
V1
25
45
15
30s
30
23
21
22
20
42
40
16
41
11s
11
10
12s
12
V2
V1

FIG. 3

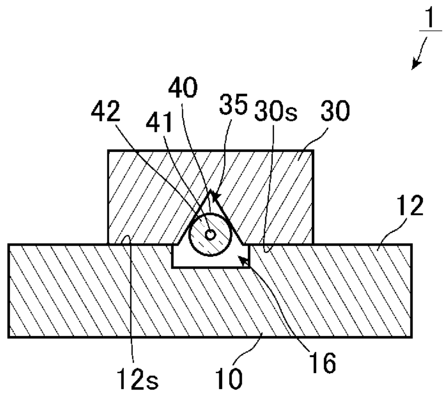


FIG. 4

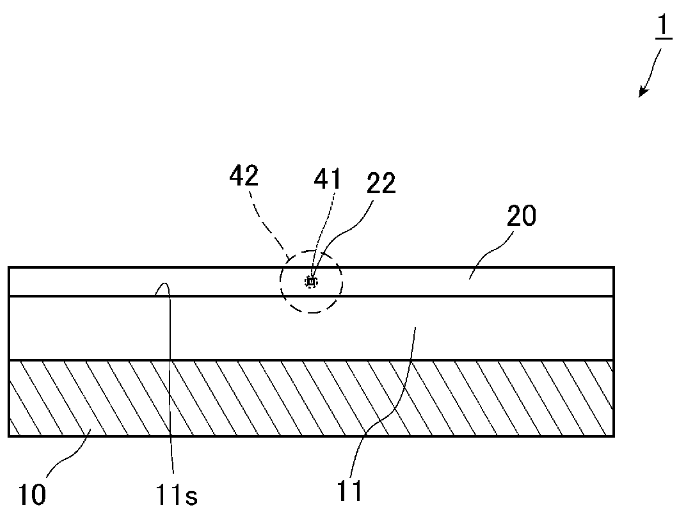


FIG. 5

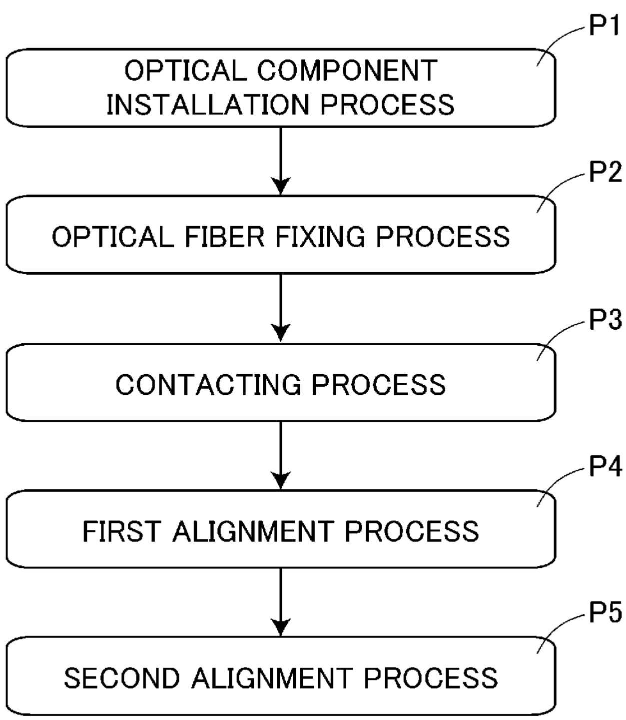

P1
OPTICAL COMPONENT INSTALLATION PROCESS
P2
OPTICAL FIBER FIXING PROCESS
P3
CONTACTING PROCESS
P4
FIRST ALIGNMENT PROCESS
P5
SECOND ALIGNMENT PROCESS

FIG. 6

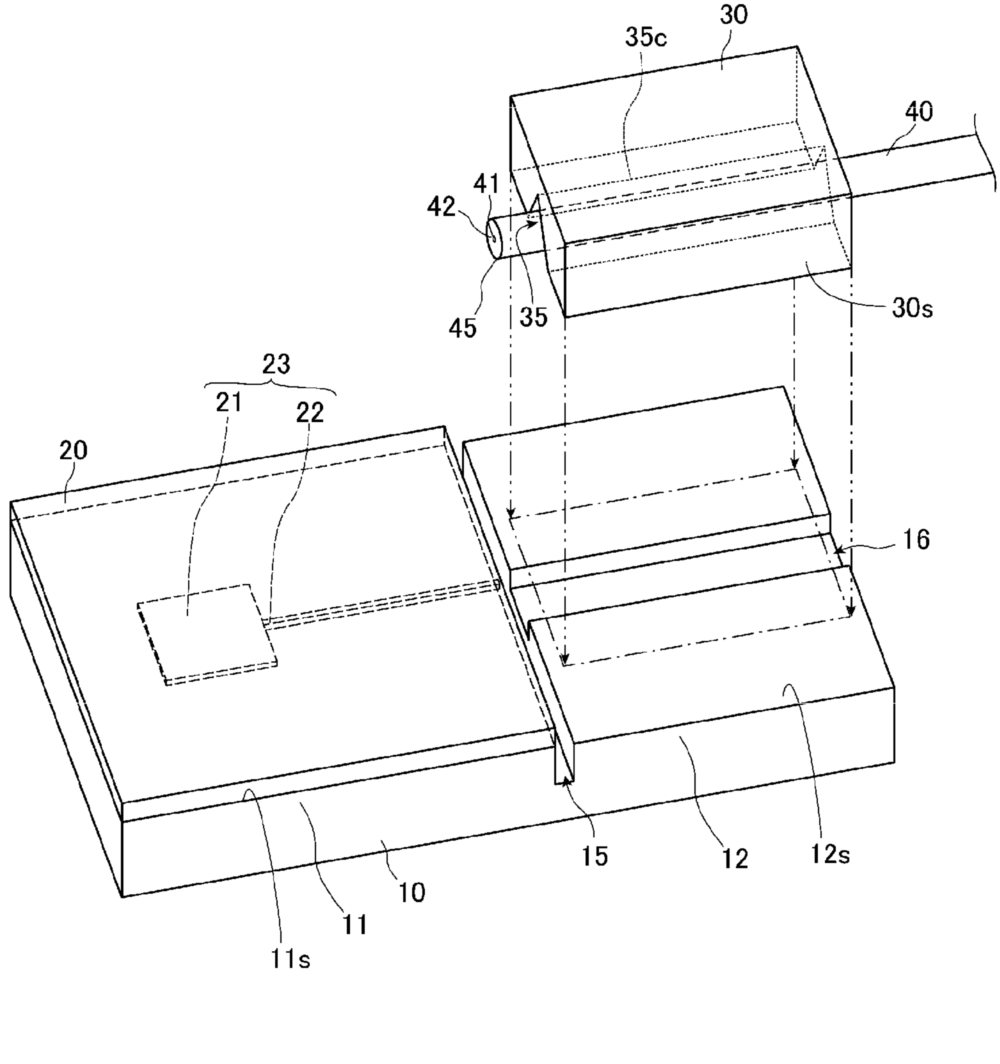


FIG. 7

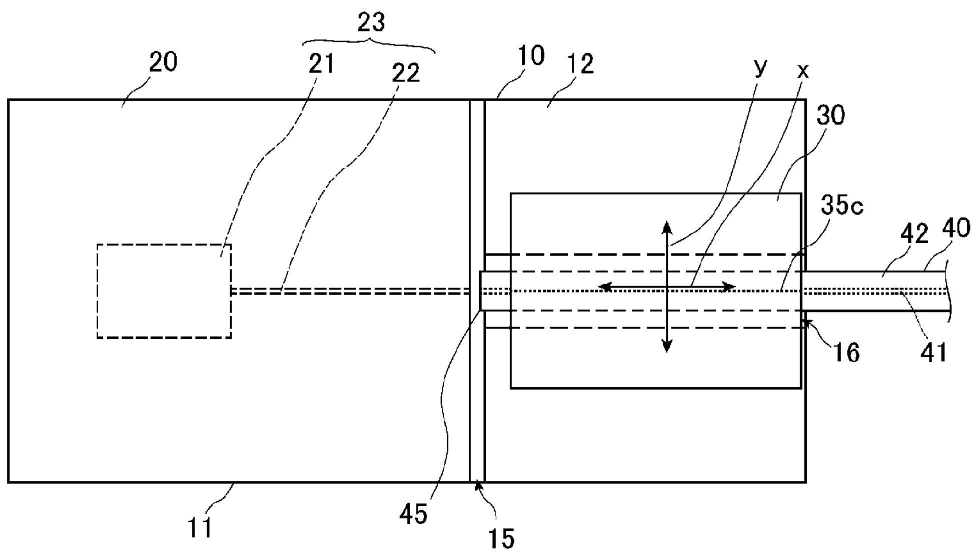


FIG. 8

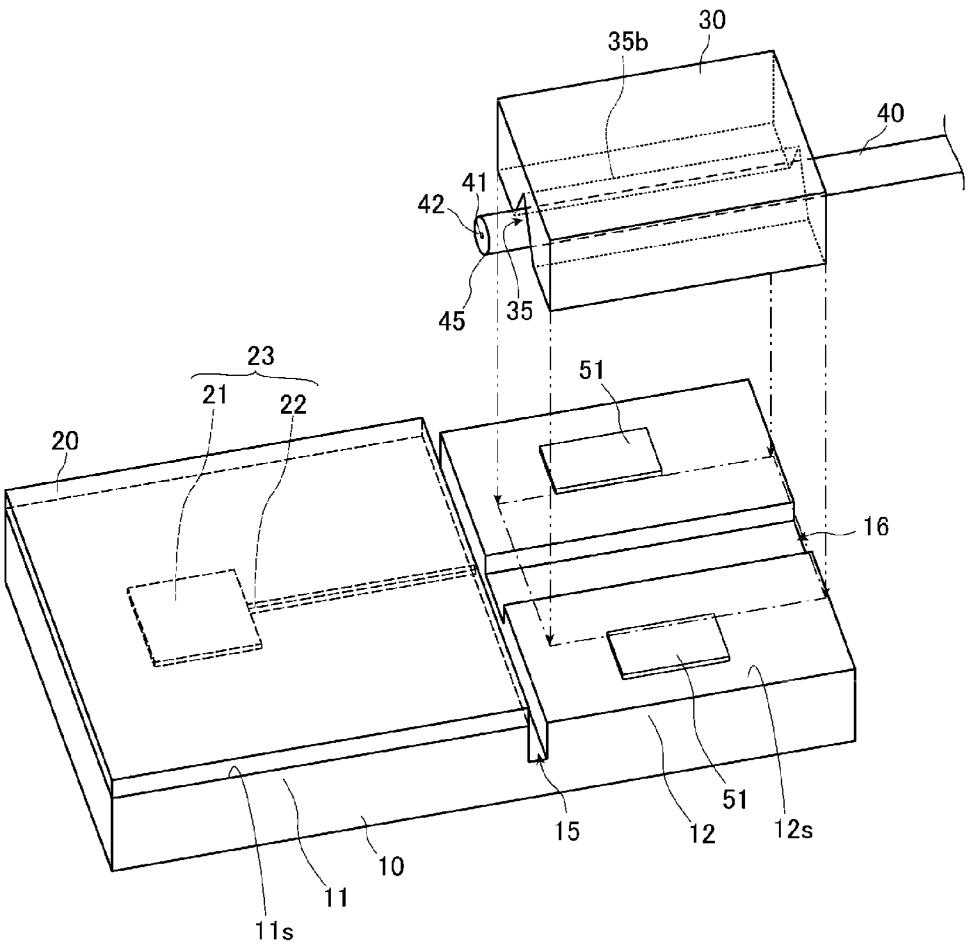


FIG. 9

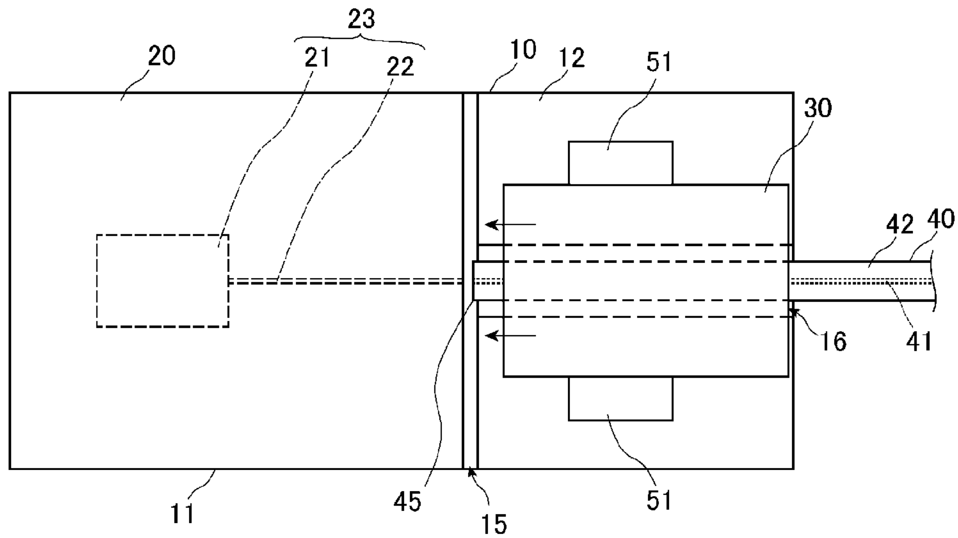


FIG. 10

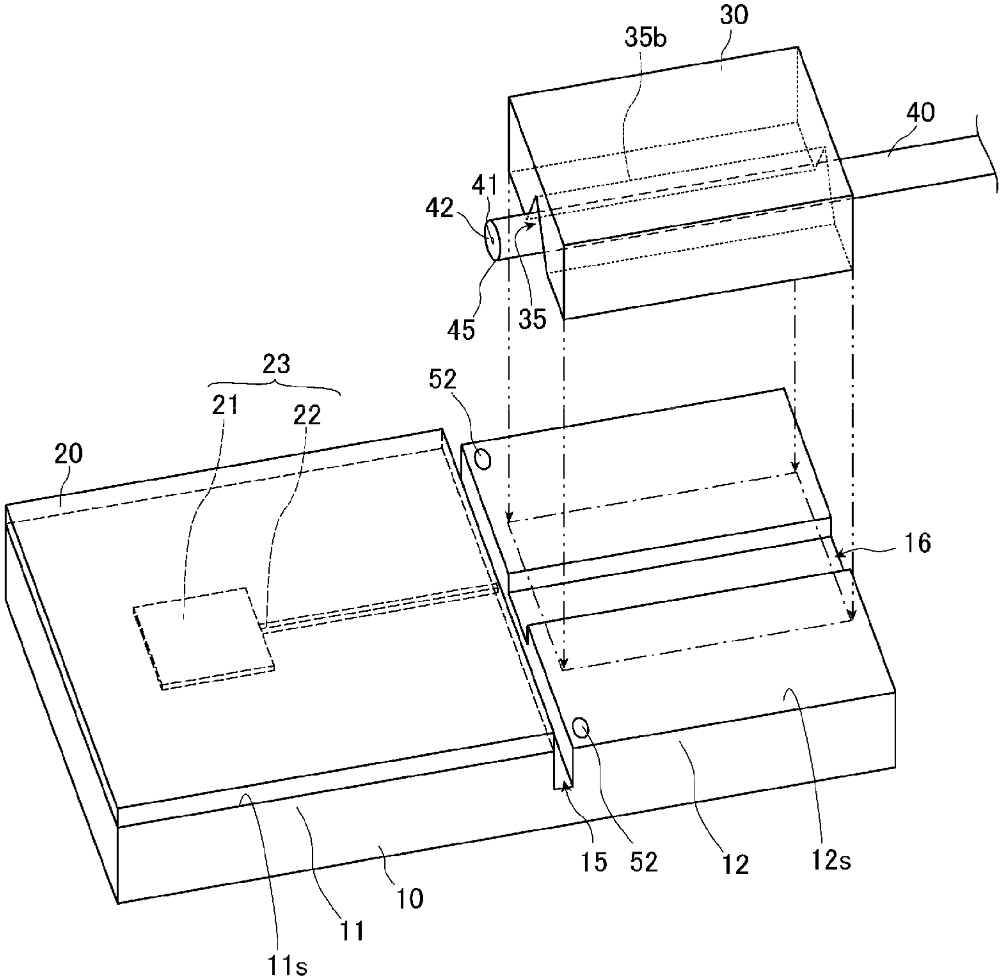


FIG. 11

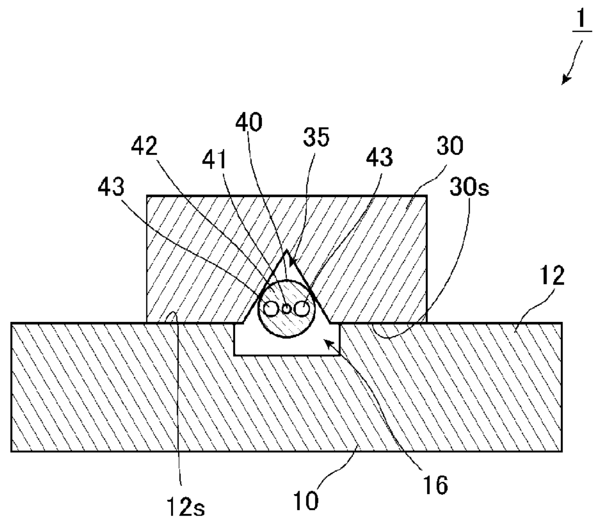

1
40
35
42
41
43
30
43
30s
12
12s
10
16

FIG. 12

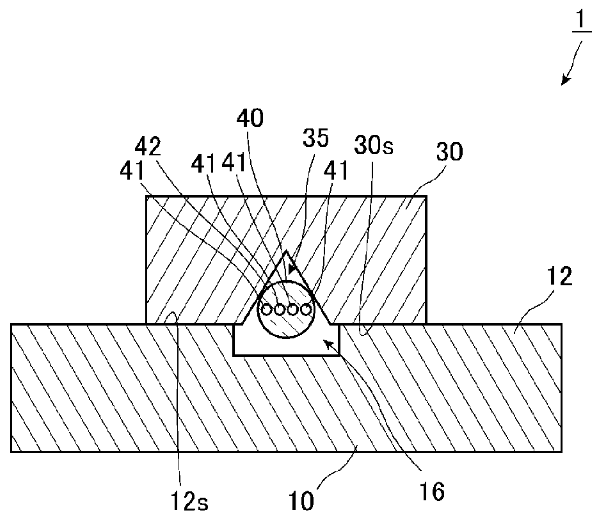
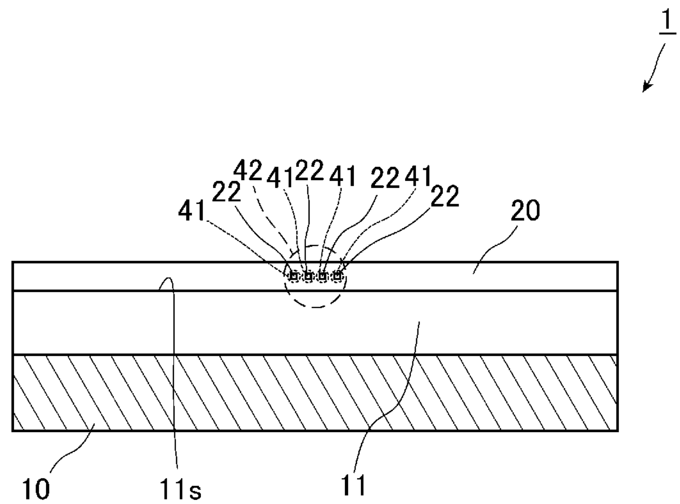

1
40
42
35
30s
30
41
41
41
41
12
12s
10
16

FIG. 13



PRODUCTION METHOD FOR OPTICAL DEVICES

TECHNICAL FIELD

[0001] The present invention relates to a manufacturing method for an optical device, the method in which an optical device allowing a reduction in optical losses can be manufactured.

BACKGROUND ART

[0002] For optical devices, an optical device is known in which an optical component, such as an optical waveguide or optical element, is installed on a substrate, the optical component is optically coupled to an optical fiber, and a light beam is entered from the optical fiber to the optical component, or a light beam from the optical component is emitted through the optical fiber.

[0003] Patent Literature 1 below describes such an optical device. The optical device described in Patent Literature 1 is fabricated in which an optical waveguide, which is an optical component, is formed on a Si substrate, a V-shaped groove is formed on the Si substrate, an optical fiber is installed on the V-shaped groove, and then the core of the optical fiber is optically coupled to the optical waveguide.

[0004] [Patent Literature 1] JP2771167 B2

SUMMARY OF INVENTION

[0005] In the optical device described in Patent Literature 1, the position of the optical fiber is defined by the V-shaped groove formed on the substrate. In the optical component on the substrate, if a portion of the optical component, which has to be optically coupled to the optical fiber (e.g. the incident end of the optical waveguide), is displaced from the core of the optical fiber, this causes optical losses. Therefore, it is important to form the V-shaped groove at a correct position or in a correct depth.

[0006] This V-shaped groove is typically formed by etching, for example. After the optical component is installed on the substrate, the physical properties of the surface of the substrate are prone to be changed by oxidation, for example, through film deposition or etching, for example, in the process of forming the optical component. In the case in which the physical properties of the surface of the substrate are changed as described above, the changes of physical properties of the surface of the substrate are not uniformly, and often resulting in roughness on the surface of the substrate. The roughness on the surface of the substrate causes the difficulty of forming the V-shaped groove at a correct position and in a correct depth.

[0007] In this case, it becomes difficult to install the optical fiber at a correct position. This causes the difficulty of preventing optical losses due to light leakage from the connecting part of the optical component to the optical fiber.

[0008] Therefore, an object of the present invention is to provide a manufacturing method for an optical device, the method in which an optical device allowing a reduction in optical losses can be easily manufactured.

[0009] In order to solve the problem, a manufacturing method for an optical device according to the present invention is a method including: an optical component installation process in which an optical component is installed on one face of a component installation substrate using a thin film process, the optical component having an end portion to be optically coupled to an optical fiber; an optical fiber fixing process in which a V-shaped groove is formed on one face side of an optical fiber fixing substrate and the optical fiber is fixed to the V-shaped groove; and a contacting process in which a part of a surface of the component installation substrate on which the optical component is provided is contacted with at least a part of a surface of the optical fiber fixing substrate on which the optical fiber is fixed.

[0010] In the manufacturing method for an optical device, the substrate to which the optical fiber is fixed and the substrate on which the optical component is installed are separate substrates. On the substrate on which the optical component is installed, the optical component is installed through a thin film process. Thus, even in the case in which the face of the component installation substrate on which the optical component is installed is roughened because the physical properties are changed due to the influence of film deposition or etching, forming the V-shaped groove on the optical fiber fixing substrate is not affected. Consequently, the V-shaped groove can be formed on the optical fiber fixing substrate at a correct position or in a correct depth. Even in the state in which the surface of the component installation substrate is roughened after the optical component is installed as described above, the physical properties on the surface are only changed, and the roughened surface hardly affects the thickness of the component installation substrate. Therefore, the V-shaped groove is accurately formed on the optical fiber fixing substrate, and then the optical fiber fixing substrate to which the optical fiber is fixed is contacted with the component installation substrate on which the optical component is installed, allowing a reduction in the displacement of the end portion of the optical component from the end portion of the optical fiber in the direction perpendicular to a contact surface. Thus, in the direction perpendicular to the longitudinal direction of the optical fiber, alignment can be easily performed at least in the direction perpendicular to the contact surface. Accordingly, an optical device allowing a reduction in optical losses can be easily manufactured.

[0011] Even in the case in which a film is deposited or a film is etched on a portion of the component installation substrate on which the optical fiber fixing substrate has to be disposed for installing the optical component, the V-shaped groove is formed, taking into account of the thickness of the thin film or the etching thickness. Thus, the displacement of the end portion of the optical component from the end portion of the optical fiber in the direction perpendicular to the contact surface can be reduced. In other words, the surface of the component installation substrate on which the optical component is provided is the surface from which the component installation substrate is directly exposed prior to installing the optical component after the optical component has been installed, or the surface on which a thin film is stacked, or the etched surface after the optical component has been installed.

[0012] Preferably, on the component installation substrate, a guide is formed to control a motion of the optical fiber fixing substrate in a direction perpendicular to a longitudinal direction of the optical fiber, in a direction in parallel with the contact surface of the optical fiber fixing substrate with the component installation substrate.

[0013] The component installation substrate is contacted with the optical fiber fixing substrate for alignment in the direction perpendicular to the contact surface. The direction perpendicular to this contact surface is also the direction perpendicular to the longitudinal direction of the optical fiber. In addition to the alignment in the direction perpendicular to the contact surface, the guide further controls the motion of the optical fiber fixing substrate in the direction in parallel with the contact surface, in the direction perpendicular to the longitudinal direction of the optical fiber. Accordingly, alignment in two directions perpendicular to the longitudinal direction of the optical fiber can be performed. In the alignment in the two directions, it is demanded to perform alignment in accuracy stricter than the accuracy of alignment along the longitudinal direction of the optical fiber. Alignment in this strict accuracy is performed on the contact surface using the guide. Thus, an optical device allowing a reduction in optical losses can be more easily manufactured

[0014] Preferably, the guide does not control the motion of the optical fiber fixing substrate along the longitudinal direction of the optical fiber.

[0015] In this case, according to the position of the end portion of the optical fiber in the longitudinal direction, the optical fiber being fixed to the optical fiber fixing substrate, the optical fiber fixing substrate is adjusted along the longitudinal direction of the optical fiber. Thus, alignment in the longitudinal direction of the optical fiber can be performed.

[0016] Preferably, the guide is formed in a process of providing the optical component.

[0017] The optical component is formed together with the guide being formed. Thus, separate processes of providing the guide can be omitted. Commonly, in the case in which a component is formed with a thin film, the controllability of positions at which thin films are formed is significantly excellent. Thus, forming the guide with a thin film allows the guide to be formed at a more correct position. Consequently, an optical device allowing a further reduction in optical losses can be manufactured.

[0018] Alternatively, preferably, the component installation substrate is provided with an alignment mark. Based on the alignment mark, a relative positional relationship between the component installation substrate and the optical fiber fixing substrate is defined.

[0019] Based on the alignment mark, the relative positions in the direction in parallel with the contact surface of the component installation substrate with the optical fiber fixing substrate can be accurately set. Thus, the position of the optical fiber fixing substrate can be more easily determined to the component installation substrate.

[0020] Alternatively, preferably, both of the end portion of the optical component and the end portion of the optical fiber are visually recognizable. An alignment process is further provided in which after the contacting process, the end portion of the optical component and the end portion of the optical fiber are visually recognized, and relative positions in the direction perpendicular to the longitudinal direction of the optical fiber are adjusted in the direction in parallel with the contact surface of the component installation substrate with the optical fiber fixing substrate.

[0021] The end portion of the optical component and the end portion of the optical fiber are visually recognized, and the relative positions of the end portion of the optical component to the end portion of the optical fiber are adjusted. Thus, the positions can be accurately adjusted. The end portion of the optical component and the end portion of the optical fiber are visually recognizable. This also includes the case in which the end portion of the optical component and the end portion of the optical fiber are shot using a camera, for example, and the end portions are visually recognized through a monitor. The wavelength of a light beam for visually recognizing the end portion of the optical component and the end portion of the optical fiber is not limited to the wavelengths of visible light, which includes the wavelengths of invisible light, such as infrared rays.

[0022] In this case, the optical fiber may be fixed in the state in which the end portion of the optical fiber protrudes from the optical fiber fixing substrate. The end portion of the optical fiber is directly visually recognized. Thus, the position adjustment process can be more easily performed.

[0023] Alternatively, the optical fiber fixing substrate may be of optical transparency. The end portion of the optical fiber may be visually recognized through the optical fiber fixing substrate.

[0024] The optical fiber is visually recognized through the optical fiber fixing substrate. Thus, alignment can be performed without the end portion of the optical fiber protruding from the optical fiber fixing substrate. In other words, the optical fiber can be fixed in such a manner that the end portion of the optical fiber is located on the inner side of the edge of the optical fiber fixing substrate. Thus, in the processes, the possibility that the end portion of the optical fiber comes into contact with other positions and is then damaged can be decreased. For example, in the case in which the optical fiber fixing substrate is made of Si, the optical fiber fixing substrate transmits infrared rays. Thus, the end portion of the optical fiber can be visually recognized using infrared rays.

[0025] Alternatively, the end portion of the optical component may be visually recognizable. The optical fiber fixing substrate may be of optical transparency. An alignment process may be further provided, in which after the contacting process, the end portion of the optical component and the center line of the V-shaped groove are visually recognized, and relative positions are adjusted in the direction parallel with the contact surface of the component installation substrate with the optical fiber fixing substrate and perpendicular to the longitudinal direction of the optical fiber.

[0026] The axis of the optical fiber disposed on the V-shaped groove is matched with the center axis of the V-shaped groove. Typically, the center position of the V-shaped groove is located at the deepest position of the V-shaped groove. The center position is seen linearly through the optical fiber fixing substrate, thus, which is easily visually recognized. Therefore, the center axis of the optical fiber can be easily grasped, allowing easy alignment. In the case in which the center line of the V-shaped groove is visually recognized, this case also includes the case in which the center line of the V-shaped groove is shot using a camera, for example, and visually recognized through a monitor. The wavelength of a light beam for visual recognition is not limited to the wavelengths of visible light, which includes the wavelengths of invisible light, such as infrared rays.

[0027] When the component installation substrate is seen in a planar view, a groove is preferably formed at a position at which the optical fiber has to be disposed so that in contacting the component installation substrate with the optical fiber fixing substrate, the optical fiber does not touch the component installation substrate.

[0028] This groove is formed. Thus, the optical fiber is not buried in the inside of the V-shaped groove. Even in the case in which a part of the optical fiber is extruded from the V-shaped groove in the thickness direction of the optical fiber fixing substrate, the substrates can be appropriately contacted with each other.

[0029] In the optical fiber fixing process, a rotation direction of the optical fiber may be adjusted relative to the center axis of the optical fiber. In this case, preferably, the optical fiber is a polarization maintaining optical fiber or a multicore optical fiber.

[0030] This case is suited for the case of using an optical fiber that is necessary to align its axis in the rotation direction relative to the center axis, like a polarization maintaining optical fiber or a multicore optical fiber, which is an optical fiber whose rotation direction is adjusted. Preferably, the rotation direction of the optical fiber is adjusted prior to disposing the optical fiber on the V-shaped groove, because of easy adjustment. However, this adjustment may be performed after the optical fiber is disposed on the V-shaped groove. Alternatively, this adjustment may be performed in disposing the optical fiber on the V-shaped groove.

[0031] As described above, according to the present invention, there is provided a manufacturing method for an optical device, the method in which an optical device allowing a reduction in optical losses can be easily manufactured.

BRIEF DESCRIPTION OF DRAWINGS

[0032] FIG. **1** is a plan view of an optical device according to an embodiment of the present invention.

[0033] FIG. **2** is a side view of the optical device illustrated in FIG. **1**.

[0034] FIG. **3** is a cross sectional view of the optical device illustrated in FIGS. **1** and **2** taken along line V_1-V_1.

[0035] FIG. **4** is a cross sectional view of the optical device illustrated in FIGS. **1** and **2** taken along line V_2-V_2.

[0036] FIG. **5** is a flowchart of the process steps of a manufacturing method for an optical device.

[0037] FIG. **6** is a diagram in which a component installation substrate is being contacted with an optical fiber fixing substrate.

[0038] FIG. **7** is a diagram of a first alignment process and a second alignment process.

[0039] FIG. **8** is a diagram in which a component installation substrate is being contacted with an optical fiber fixing substrate according to a second embodiment.

[0040] FIG. **9** is a diagram of an alignment process according to the second embodiment.

[0041] FIG. **10** is a diagram in which a component installation substrate is being contacted with an optical fiber fixing substrate according to a third embodiment.

[0042] FIG. **11** is a diagram of an optical device according to a fourth embodiment similarly viewed as in FIG. **3**.

[0043] FIG. **12** is a diagram of the optical device according to a fifth embodiment similarly viewed as in FIG. **3**.

[0044] FIG. **13** is a diagram of an optical device according to the fifth embodiment similarly viewed as in FIG. **4**.

DESCRIPTION OF EMBODIMENTS

[0045] In the following, preferred embodiments of a manufacturing method for an optical device according to the present invention will be described in detail with reference to the drawings. For easy understanding, scales described in the drawings are sometimes different from scales described in the following description.

First Embodiment

[0046] FIG. **1** is a diagram of an optical device according to an embodiment of the present invention, and FIG. **2** is a side view of the optical device illustrated in FIG. **1**. FIG. is a cross sectional view of the optical device illustrated in FIGS. **1** and **2** taken along line V_1-V_1. FIG. **4** is a cross sectional view of the optical device illustrated in FIGS. **1** and **2** taken along line V_2-V_2.

[0047] As illustrated in FIGS. **1** and **2**, an optical device **1** includes a component installation substrate **10**, an optical layer **20** provided on the component installation substrate **10**, an optical fiber fixing substrate **30** disposed on the component installation substrate **10**, and an optical fiber **40** fixed to the optical fiber fixing substrate **30** as main configurations.

[0048] The component installation substrate **10** has a nearly rectangular shape in a planar view from one face side. On the one face side of the component installation substrate **10**, a groove **15** is formed. One side relative to the groove **15** is an optical component installation area **11**. The other side of the groove **15** is an optical fiber disposition area **12**. A surface **11***s* of the optical component installation area **11** is flush with a surface **12***s* of the optical fiber disposition area **12**, which are separated by the groove **15**. On the optical fiber disposition area **12**, a groove **16** is formed. The groove **16** extends in the direction orthogonal to the groove **15**, and is formed shallower than the groove **15**.

[0049] On the surface **11***s* on the optical component installation area **11**, the optical layer **20** is provided. The optical layer **20** is formed of a plurality of thin films. Specifically, the optical layer **20** is configured of a lower layer formed on the surface **11***s*, an upper layer formed on the lower layer, and an optical element layer **21** and a waveguide **22** formed between the lower layer and the upper layer. However, in FIGS. **2** and **4** in which the lower layer and the upper layer can be visually recognized, the boundary between the lower layer and the upper layer is omitted. The lower layer and the upper layer are made of SiO2, for example. The optical element layer **21** is a layer that receives a light beam for a predetermined optical operation, which is a photodiode layer, for example. The waveguide **22** is made of Si. Thus, the waveguide **22** can guide a light beam at a predetermined wavelength based on the refractive index difference between the lower layer and the upper layer. For example, the waveguide **22** has a thickness of 0.5 μm, and has its width nearly equal to its thickness. The waveguide **22** can propagate a light beam at a wavelength of 1,550 nm in a single mode. The waveguide **22** is optically coupled to the optical element layer **21**. A light beam is entered and propagated through the waveguide **22**, and entered to the optical element layer **21**. A light beam is emitted from the optical element layer **21**, propagated through the waveguide **22**, and then emitted from the waveguide **22**. In the embodiment, an optical component **23** is configured of the optical element layer **21** and the waveguide **22**. The waveguide **22** extends to the edge on the groove **15** side of the optical layer **20**. An end portion **25** on the groove **15** side of the waveguide **22** is the end portion **25** that has to be optically coupled to the optical fiber **40**. On the end portion **25**, a mode field diameter converting portion is installed for matching the mode field diameter with the optical fiber **40** as necessary.

[0050] The optical fiber fixing substrate **30** has a size in which the optical fiber fixing substrate **30** can be disposed on the surface **12***s* of the optical fiber disposition area **12** of the component installation substrate **10**. The optical fiber fixing substrate **30** is disposed on the surface **12***s* of the optical fiber disposition area **12** so as to cover at least a part of the groove **16** formed on the surface **12***s* side of the optical fiber disposition area **12**. As illustrated in FIG. **3**, on the optical fiber disposition area **12** side of the optical fiber fixing substrate **30**, a V-shaped groove **35** is linearly formed. In the state in which the optical fiber fixing substrate **30** is disposed on the optical fiber disposition area **12**, the V-shaped groove **35** is provided along the longitudinal direction of the groove **16**, i.e. along the direction that is perpendicular to the longitudinal direction of the groove **15** formed on the component installation substrate **10**. In other words, the optical fiber fixing substrate **30** is disposed on the optical fiber disposition area **12** in such a manner that the V-shaped groove **35** is directed in this direction. The surface **12***s* of the component installation substrate **10** is fixed to a surface **30***s* of the optical fiber fixing substrate **30** on the V-shaped groove side by fusion splicing or attachment. In fixing by attachment, contacting the surface **12***s* of the component installation substrate **10** with the surface **30***s* of the optical fiber fixing substrate **30** includes the case in which the surface **12***s* is touched and contacted with the surface **30***s* as well as the case in which the surface **12***s* is contacted with the surface **30***s* through an adhesive.

[0051] The optical fiber **40** includes a core **41** and a cladding that covers the outer circumferential surface of the core **41**. This core **41** has a predetermined refractive index difference between the cladding **42**, and has a predetermined diameter. Through the core **41**, a light beam can be propagated in a single mode. At the wavelength of this light beam, the light beam is propagated through the waveguide **22** in a single mode. The optical fiber **40** is fixed to the V-shaped groove **35** along the longitudinal direction of the V-shaped groove **35** formed on the optical fiber fixing substrate **30**. In the embodiment, the optical fiber **40** is fixed to the V-shaped groove **35** in such a manner that one end portion **45** of the optical fiber **40** protrudes from the optical fiber fixing substrate **30**. As illustrated in FIG. **3**, the optical fiber **40** is not buried in the inside of the V-shaped groove **35**. The optical fiber is extruded from the V-shaped groove in the diameter direction. However, in the state in which the optical fiber fixing substrate **30** is disposed on the optical fiber disposition area **12** of the component installation substrate **10**, a part of the optical fiber **40** is located in the inside of the groove **16**, and the optical fiber **40** is not in contact with the component installation substrate **10**. As illustrated in FIG. **4**, the end portion **25** of the waveguide **22** is connected to the one end portion **45** of the optical fiber **40**. The waveguide **22** is optically coupled to the core **41** of the optical fiber **40**.

[0052] In the optical device **1** thus configured, in the case in which a light beam is propagated through the core **41** of the optical fiber **40** toward the waveguide **22**, the light beam reaches the optical element layer **21** through the waveguide **22**. On the other hand, in the case in which the optical element layer **21** emits a light beam to the waveguide **22**, the light beam is propagated from the waveguide **22** to the optical fiber.

[0053] Next, a manufacturing method for the optical device **1** will be described.

[0054] FIG. **5** is a flowchart of the process steps of a manufacturing method for the optical device **1**. As illustrated in FIG. **5**, the manufacturing method for the optical device **1** according to the embodiment includes an optical component installation process P**1**, an optical fiber fixing process P**2**, a contacting process P**3**, a first alignment process P**4**, and a second alignment process P**5**. FIG. **6** is a diagram in which the component installation substrate **10** on which the optical layer **20** is installed is being contacted with the optical fiber fixing substrate **30** to which the optical fiber **40** is fixed.

[0055] <Optical Component Installation Process P**1**>First, a substrate to be the component installation substrate **10** is prepared. In the embodiment, this substrate is a silicon substrate whose surface is oxidized. In other words, the substrate is mainly formed of Si, and its surface is a SiO_2 layer. The SiO_2 layer corresponds to the lower layer of the optical layer **20**. The substrate is a flat-plate substrate. The grooves **15** and **16** are not formed on the substrate.

[0056] Subsequently, on the SiO_2 layer of the silicon substrate, the optical element layer **21** and the waveguide **22** formed of the Si layer are formed. The optical element layer **21** and the waveguide **22** are formed by a thin film process that is the combination of a film deposition processes, for example, chemical vapor deposition (CVD), vapor deposition, etc. and a removal process, for example etching process, in which unnecessary portions are removed. At this time, the waveguide **22** is formed in such a manner that the waveguide **22** extends to reach to the region on which the groove **15** should be formed. Subsequently, a SiO_2 film is deposited on a region to be the optical component installation area **11**. The SiO_2 film is the upper layer of the optical layer **20**. At this time, the SiO_2 film is deposited in such a manner that the upper layer is extruded to a region in which the groove **15** should be formed. In this manner, the optical element layer **21** and the waveguide **22** are sandwiched between the lower layer and the upper layer made of SiO_2. In this process, in the case in which a film is deposited on the optical fiber disposition area **12** or in the case in which the optical fiber disposition area **12** is etched, the surface **12***s* of the optical fiber disposition area **12** is the surface including the deposited film, or the etched surface.

[0057] In addition to the silicon substrate whose surface is oxidized, for the substrate which is to be the component installation substrate **10**, an SOI (silicon on insulator) substrate can be used as well, which has a SiO_2 layer is inserted between a Si substrate and a Si layer, in surface, for example. In this case, the Si layer on the surface is etched to form the waveguide **22**, and then the upper layer is formed similarly to the description above.

[0058] Subsequently, relative to a location at which the groove **15** should be formed, the groove **16** is formed by etching on the region on the opposite side of the region on which the optical layer **20** is formed. At this time, the groove **16** is formed so as to extend to reach to the region in which the groove **15** should be formed.

[0059] Subsequently, the groove **15** is formed. The groove **15** is formed by dicing, for example. As described above, the waveguide **22** extends to reach to the region in which the groove **15** should be formed. Thus, the waveguide **22** is exposed from the side surface of the optical layer **20** by dicing. The end portion including the portion from which the waveguide **22** is exposed is the end portion **25** that should be optically coupled to the core of the optical fiber **40**. The groove **15** is formed deeper than the groove **16**. As described above, the groove **16** is formed so as to extend to reach to the region in which the groove **15** should be formed, therefore the groove **16** is connected to the groove **15** at forming of the groove **15**. After forming the groove **15**, the optical layer **20** is deposited side area of groove **15** is the optical component installation area **11**, the groove **16** formed side area of groove **15** is the optical fiber disposition area **12**. In this manner, the grooves **15** and **16** are formed. Consequently, the component installation substrate **10** is formed from the prepared substrate. Note that, the groove **15** can be formed on the region in contact with the groove **16**. The groove **15** does not necessarily have to be formed across from the one side surface of the component installation substrate **10** to the other side surface.

[0060] In the case in which the optical component **23** is installed using the thin film process including film deposition and etching as described above, the total of the thickness of a film deposition and etching for forming the end portion **25** of the optical component **23** that should be connected to the optical fiber, is preferably no more than 2.5 times the mode field diameter of a light beam propagated through the optical fiber **40**. The reason is as follows. Commonly, the thickness of a thin film deposited through the film deposition process has errors within 10% with respect to the thickness of a thin film having a design value for deposition. Similarly, the thickness of a thin film to be removed through etching processes commonly has errors within 10% with respect to the thickness of a thin film having a design value for removal. Commonly, in the case in which the displacement of the axis of the core **41** of the optical fiber **40** at the end portion **45** from the axis of the end portion **25** of the optical component **23** is 25% or less of the mode field diameter of a light beam propagated through the optical fiber **40**, an optical loss at the connecting part of the end portion **25** of the optical component **23** to the end portion **45** of the optical fiber **40** is one decibel or less. Thus, even in the case in which the position of the end portion **25** of the optical component **23** is displaced due to errors in the film thickness by film deposition or etching, the positional displacement of the end portion **25** of the optical component **23** from the end portion **45** of the optical fiber **40** is preferably 25% or less of the mode field diameter. Therefore, the above total of the thickness of the film deposition and etching for forming the end portion **25** of the optical component **23** is preferably 2.5 times or less of the mode field diameterbased on 0.25/0.10=2.5.

[0061] As illustrated in FIG. **6**, through the thin film process described above, the optical component **23** formed of the optical element layer **21** and the waveguide **22** is installed on the component installation substrate **10**. Note that, the forming method for the optical component **23** is an example. The optical component **23** may be formed on the component installation substrate **10** by other forming methods.

[0062] <Optical Fiber Fixing Process P2>

[0063] In this process, first, a substrate to be the optical fiber fixing substrate **30**, to which the optical fiber **40** is fixed, and the optical fiber **40** are prepared. This substrate does not have the V-shaped groove **35** formed, and has a flat-plate shape. This substrate is a substrate made of Si, for example, through which a light beam at a specific wavelength is transmitted. In the case in which the cladding **42** of the optical fiber **40** is covered with a protective layer made of a resin, for example, its buffer layer is removed from the end portion **45** in a predetermined length.

[0064] Subsequently, the V-shaped groove **35** is formed on one face of the prepared substrate. Commonly, the V-shaped groove **35** is formed by etching processes. However, the V-shaped groove **35** may be formed by cutting. In disposing the optical fiber fixing substrate **30** on the component installation substrate **10** as described later, the V-shaped groove **35** is formed in such a manner that the axis of the core **41** of the optical fiber **40** is matched with the axis of the waveguide **22** in the direction perpendicular to the contact surface of the component installation substrate **10** with the optical fiber fixing substrate **30**. Thus, in the optical component installation process P**1**, in the case in which a thin film is stacked on the optical fiber disposition area **12** of the component installation substrate **10** or in the case in which the optical fiber disposition area **12** is etched, the size of the V-shaped groove **35** is determined, taking into account of the thin film to be stacked or the amount of etching. In this manner, the V-shaped groove **35** is formed on the prepared substrate, and the substrate is the optical fiber fixing substrate **30**.

[0065] Subsequently, the optical fiber **40** is disposed on the V-shaped groove **35**, and the optical fiber **40** is fixed to the optical fiber fixing substrate **30**. At this time, the optical fiber **40** is preferably disposed on the V-shaped groove in such a manner that the end portion **45** protrudes from the optical fiber fixing substrate **30**. The optical fiber **40** is thus disposed, allowing the optical fiber **40** to be directly visually recognized in the stage in which the position of the optical fiber **40** is adjusted. The optical fiber **40** is fixed to the optical fiber fixing substrate **30** using an adhesive, for example.

[0066] This process and the optical component installation process P**1** may be performed at the same time. Alternatively, the optical component installation process P**1** may be performed after this process.

[0067] <Contacting Process P3>Next, the contacting process P**3** is performed. As illustrated in FIG. **6**, in this process, a part of the surface of the component installation substrate **10**, on which the optical component **23** is provided, is contacted with at least a part of the surface of the optical fiber fixing substrate **30** to which the optical fiber **40** is fixed.

[0068] Specifically, the optical fiber fixing substrate **30** is disposed on the component installation substrate **10** in such a manner that the surface **12***s* of the optical fiber disposition area **12** of the component installation substrate **10** is contacted with the surface **30***s* of the optical fiber fixing substrate **30** to which the optical fiber **40** is fixed. At this time, even in the case in which a part of the optical fiber **40** is extruded from the V-shaped groove **35** in the direction perpendicular to the surface **30***s*, the extruded portion of the optical fiber **40** is accommodated in the inside of the groove **16** formed on the component installation substrate **10**. Thus, the groove **16** prevents that the extruded portion of the optical fiber **40** obstructing the contact of the surface **12***s* of the optical fiber disposition area **12** with the surface **30***s* of the optical fiber fixing substrate **30**.

[0069] As described above, the V-shaped groove **35** is formed in such a manner that the axis of the waveguide **22** is matched with the axis of the core **41** of the optical fiber **40** in the direction perpendicular to the contact surface of the component installation substrate **10** with the optical fiber fixing substrate **30**. Thus, in this process, the alignment of the end portion **25** of the optical component **23** with the end portion **45** of the optical fiber **40** is completed in the direction perpendicular to the contact surface of the component installation substrate **10** with the optical fiber fixing substrate **30**.

[0070] <First Alignment Process P**4**>

[0071] Next, the first alignment process is performed. FIG. **7** is a diagram of the first alignment process P**4** and the second alignment process P**5** according to the embodiment. In the first alignment process P**4**, the gap between the end portion **25** of the optical component **23** and the end portion **45** of the optical fiber **40** is adjusted by moving the optical fiber fixing substrate **30** along the longitudinal direction of the optical fiber **40**. In other words, the optical fiber fixing substrate **30** is moved in the x-direction illustrated in FIG. **7**. By this process, in the case in which it is desired to provide a zero gap between the end portion **25** of the optical component **23** and the end portion **45** of the optical fiber **40**, for example, the optical fiber fixing substrate **30** is moved in the x-direction in such a manner that the end portion **45** of the optical fiber **40** comes into contact with the end portion **25** of the optical component **23**. In the case in which a predetermined gap is provided between the end portion **25** of the optical component **23** and the end portion **45** of the optical fiber **40**, the optical fiber fixing substrate **30** is moved in the x-direction in such a manner that this predetermined gap is provided between the end portion **25** of the optical component **23** and the end portion **45** of the optical fiber **40**.

[0072] The optical fiber fixing substrate **30** is preferably moved while visually recognizing the end portion **45** of the optical fiber **40**. At this time, preferably, the optical fiber **40** is shot using a camera, and the shot image is monitored to visually recognize the optical fiber **40**.

[0073] As illustrated in the drawings in the embodiment, in the case in which the end portion **45** of the optical fiber **40** protrudes from the optical fiber fixing substrate **30**, the optical fiber fixing substrate **30** is moved in the x-direction while directly visually recognizing the end portion **45** of the optical fiber **40**. In the case of visual recognition using a camera as described above, the optical fiber **40** is directly shot by the camera for visual recognition.

[0074] On the other hand, unlike the drawings in the embodiment, in the case in which the end portion **45** of the optical fiber **40** does not protrude from the optical fiber fixing substrate **30** along the longitudinal direction of the optical fiber **40**, the end portion **45** of the optical fiber **40** is visually recognized through the optical fiber fixing substrate **30**. In this case, it is necessary that the optical fiber fixing substrate **30** be of optical transparency, through which at least a light beam at a predetermined wavelength is transmitted. When the optical fiber fixing substrate **30** is of optical transparency, the end portion **45** of the optical fiber **40** is visually recognized with a light beam at a wavelength at which the light beam is transmitted through the optical fiber fixing substrate **30**. For example, in the case in which the optical fiber fixing substrate **30** is made of Si, the optical fiber **40** can be visually recognized using infrared rays.

[0075] Alternatively, this process may be performed without visually recognizing the end portion **45** of the optical fiber **40**. For example, in the case in which the optical fiber fixing substrate **30** is moved in the x-direction in such a manner that the end portion **45** of the optical fiber comes into contact with the end portion **25** of the optical component **23** as described above, the end portion **45** of the optical fiber **40** is not necessarily visually recognized specifically. However, in order to reduce the damage to the optical fiber **40** in this alignment process, the end portion **45** of the optical fiber **40** is preferably visually recognized. Alternatively, in the case in which the optical component **23** is optically operable, the optical fiber fixing substrate **30** may be moved based on the measured result, in which a light beam is emitted from the optical fiber **40** to the optical component **23** for measuring an output from the optical component **23**, or in which a light beam is emitted from the optical component **23** to the optical fiber **40** for measuring an output from the optical fiber **40**. In the case in which the distance from the end portion **45** of the optical fiber **40** to the end face on the optical component **23** side of the optical fiber fixing substrate **30** is known, e.g. in the case in which the end portion **45** of the optical fiber **40** is located in the inside of the V-shaped groove **35** and the distance from the end portion **45** to the end face on the optical component **23** side of the optical fiber fixing substrate **30** is known, the position of the end portion **45** of the optical fiber **40** may be adjusted by adjusting the position of the optical fiber fixing substrate **30** in such a manner that a predetermined distance is provided between the end portion **25** of the optical component **23** and the end face of the optical fiber fixing substrate **30**. In order to dispose the optical fiber **40** on the optical fiber fixing substrate **30** as described above, the optical fiber **40** may be disposed in the inside of the V-shaped groove **35** in the optical fiber fixing process P**2** in such a manner that the distance from the end face of the optical fiber fixing substrate **30** to be the optical component **23** side to the end portion **45** of the optical fiber **40** is a predetermined distance.

[0076] Alternatively, the distance from the end face of the optical fiber fixing substrate **30** to be the optical component **23** side to the end portion **45** of the optical fiber **40** may be measured after the optical fiber **40** is disposed in the inside of the V-shaped groove **35**.

[0077] Thus, alignment in the longitudinal direction of the optical fiber **40** is completed.

[0078] <Second Alignment Process P**5**>

[0079] Next, the second alignment process is performed. In the second alignment process P**5**, in the direction in parallel with the contact surface of the component installation substrate **10** with the optical fiber fixing substrate **30**, the optical fiber fixing substrate **30** is moved along the direction perpendicular to the longitudinal direction of the optical fiber **40**, and the relative positions of the component installation substrate **10** to the optical fiber fixing substrate **30** are adjusted. In other words, the optical fiber fixing substrate **30** is moved in the y-direction illustrated in FIG. **7**. In this process, the end portion **25** of the optical component **23** is aligned with the end portion **45** of the optical fiber **40** in the direction perpendicular to the longitudinal direction of the optical fiber **40**. Thus, the position of the optical fiber fixing substrate **30** in the y-direction is adjusted in such a manner that the axis of the end portion **25** of the optical component **23** is matched with the axis of the end portion **45** of the optical fiber **40**.

[0080] The optical fiber fixing substrate **30** is preferably moved while visually recognizing the end portion **25** of the optical component **23** and the core **41** at the end portion **45** of the optical fiber **40**. In this case, preferably, the end portion **25** of the optical component **23** and the core **41** at the end portion **45** of the optical fiber **40** are shot using a camera, and the shot image is monitored for visually recognizing the end portion **25** of the optical component **23** and the core **41** at the end portion **45** of the optical fiber **40**.

[0081] In this process, as illustrated in the drawings in the embodiment, in the case in which the end portion **45** of the optical fiber **40** protrudes from the optical fiber fixing substrate **30**, the core **41** at the end portion **45** of the optical fiber **40** is directly visually recognized, and the optical fiber fixing substrate **30** is moved in the y-direction. As described above, in the case of visual recognition using a camera, the optical fiber **40** is directly shot using a camera for visual recognition.

[0082] On the other hand, unlike the drawings in the embodiment, in the case in which the end portion **45** of the optical fiber **40** does not protrude from the optical fiber fixing substrate **30** along the longitudinal direction of the optical fiber **40**, the core **41** at the end portion **45** of the optical fiber **40** is visually recognized through the optical fiber fixing substrate **30**. Alternatively, in this case, a center line **35***c* of the V-shaped groove **35** may be visually recognized without visually recognizing the optical fiber **40**. The reason is that in the case in which the optical fiber **40** is disposed on the V-shaped groove **35**, the center line **35***c* of the V-shaped groove **35** is matched with the axis of the optical fiber **40** (the axis of the core **41**) when viewed in the depth direction of the V-shaped groove **35**. In the case in which the core **41** of the optical fiber **40** or the center line **35***c* of the V-shaped groove **35** is visually recognized through the optical fiber fixing substrate **30**, it is necessary that the optical fiber fixing substrate **30** be of optical transparency in which at least a light beam at a predetermined wavelength is transmitted. When the optical fiber fixing substrate **30** is of optical transparency, the end portion **45** of the optical fiber **40** is visually recognized with a light beam at a wavelength at which the light beam is transmitted through the optical fiber fixing substrate **30**. For example, in the case in which the optical fiber fixing substrate **30** is made of Si, the optical fiber **40** can be visually recognized using infrared rays.

[0083] For example, as illustrated in the drawings in the embodiment, in the case in which the end portion **25** of the optical component **23** is not exposed from the upper layer of the optical layer **20**, the end portion **25** of the optical component **23** is visually recognized through the upper layer of the optical layer **20**. In the case in which the end portion **25** is visually recognized through the upper layer of the optical layer **20**, it is necessary that the upper layer be of optical transparency in which at least a light beam at a predetermined wavelength is transmitted. When the upper layer is of optical transparency, the end portion **25** of the optical component **23** is visually recognized using a light beam at a wavelength at which the light beam is transmitted through the upper layer. For example, in the case in which the upper layer of the optical layer **20** is made of Si as described above, the end portion **25** of the optical component **23** can be visually recognized using infrared rays. In this case, when the optical fiber fixing substrate **30** is made of Si as described above, the core **41** of the optical fiber **40**, the center line **35***c* of the V-shaped groove **35** of the optical fiber fixing substrate **30**, and the end portion **25** of the optical component **23** can be visually recognized at the same time using infrared rays. On the other hand, unlike the drawings in the embodiment, in the case in which the end portion **25** of the optical component **23** is exposed, the end portion **25** of the optical component **23** is directly visually recognized.

[0084] This process may be performed without visually recognizing the end portion **25** of the optical component **23**. For example, in the case in which the optical component **23** is optically operable, the optical fiber fixing substrate **30** can be moved in the y-direction based on the measured result, in which a light beam is emitted from the optical fiber **40** to the optical component **23** for measuring an output from the optical component **23**, or in which a light beam is emitted from the optical component **23** to the optical fiber **40** for measuring an output from the optical fiber **40**.

[0085] Thus, in the direction in parallel with the contact surface of the component installation substrate **10** with the optical fiber fixing substrate **30**, alignment in the direction perpendicular to the longitudinal direction of the optical fiber **40** is completed. Note that, this process and the first alignment process P4 may be performed at the same time. Alternatively, the first alignment process P4 may be performed after this process.

[0086] Subsequently, the component installation substrate **10** is fixed to the optical fiber fixing substrate **30**. The component installation substrate **10** is fixed to the optical fiber fixing substrate **30** by fusion splicing or adhension. Fusion splicing is performed by laser fusion splicing or ultrasonic bonding, for example. For example, adhension may be performed as below. An adhesive is coated on the surface **30***s* of the optical fiber fixing substrate **30** in advance, and the adhesive is then hardened. Alternatively, after the completion of the alignment process, an adhesive is coated over the edge of the surface **30***s* of the optical fiber fixing substrate **30** and the surface **12***s* of the optical fiber disposition area **12** of the component installation substrate **10**, and then the adhesive is hardened.

[0087] Thus, the optical device **1** illustrated in FIGS. **1** to **4** is obtained.

[0088] As described above, in accordance with the manufacturing method for the optical device **1** according to the embodiment, the optical fiber fixing substrate **30**, to which the optical fiber **40** is fixed, and the component installation substrate **10**, on which the optical component **23** is installed, are separate substrates. On the component installation substrate **10**, the optical component **23** is installed through the thin film process. Thus, even in the case in which the surface **12***s* of the optical fiber disposition area **12** of the component installation substrate **10** is roughened and the physical properties are changed due to the influence of etching, forming the V-shaped groove **35** on the optical fiber fixing substrate **30** is not affected. Therefore, the V-shaped groove **35** can be formed at a correct position or in a correct size on the optical fiber fixing substrate **30**. Even in the state in which the surface **12***s* of the optical fiber disposition area **12** is roughened after the optical component **23** is installed, the physical properties on the surface are only changed, hardly affecting the thickness of the component installation substrate **10**. Thus, the V-shaped groove **35** is accurately formed on the optical fiber fixing substrate **30**, and the optical fiber fixing substrate **30** to which the optical fiber **40** is fixed is contacted with the component installation substrate **10**. Consequently, the displacement of the end portion **25** of the optical component **23** from the end portion **45** of the optical fiber **40** in the direction perpendicular to the contact surface can be reduced, and the alignment of the optical fiber **40** is completed in the direction perpendicular to the contact surface of each of the substrates. As described above, in the alignment direction of the position of the optical fiber **40**, alignment can be easily performed at least in the direction perpendicular to the contact surface. Accordingly, an optical device **1** allowing a reduction in optical losses can be easily manufactured.

Second Embodiment

[0089] Next, referring to FIGS. **8** and **9**, a second embodiment of the present invention will be described in detail. Components the same as or equivalent to ones in the first embodiment are designated the same reference numerals and signs, and the overlapping description is omitted unless otherwise specified.

[0090] FIG. **8** is a diagram in which the component installation substrate **10** is being contacted with the optical fiber fixing substrate **30** in the embodiment. As illustrated in FIG. **8**, the component installation substrate according to the embodiment is different from the component installation substrate **10** according to the first embodiment in that a pair of guides **51** is provided on the surface **12***s* of the optical fiber disposition area **12**. In disposing the optical fiber fixing substrate **30** on the component installation substrate **10**, these guides **51** control the motion of the optical fiber fixing substrate **30** in the direction perpendicular to the longitudinal direction of the optical fiber **40** (in the y-direction in FIG. **7**), in the direction in parallel with the contact surface of the optical fiber fixing substrate **30** with the component installation substrate **10**, and the guides **51** do not control the motion of the optical fiber fixing substrate **30** in the direction along the longitudinal direction of the optical fiber **40** (illustrated in FIG. **7** in the x-direction).

[0091] The guides **51** are spaced with a gap the same as the width of the optical fiber fixing substrate **30** in the direction perpendicular to the longitudinal direction of the optical fiber **40**. Therefore, the pair of guides **51** controls the motion of the optical fiber fixing substrate **30** by sandwiching the opposite side surfaces of the optical fiber fixing substrate **30** on the component installation substrate **10**. Thus, in disposing the optical fiber fixing substrate **30** on the component installation substrate **10**, the pair of guides **51** is provided at locations in such a manner that the optical fiber fixing substrate **30** is located as the axis of the end portion **25** of the optical component **23** is matched with the axis of the end portion **45** of the optical fiber **40**.

[0092] In order to provide these guides **51**, the guides can be formed in the optical component installation process P**1** in the first embodiment. The guides **51** are preferably formed together with the optical component **23** in the thin film process of forming the optical component **23**. Commonly, the controllability of positions at which thin films are formed is significantly excellent. Thus, forming the guides **51** with a thin film allows the guides **51** to be formed at more correct positions. Specifically, forming the guides **51** together with the optical component **23** allows using the same mask which contains patterns of the optical component and the guides **51**. Consequently, the positional correlation of the optical component **23** with the guides **51** can be appropriately controlled.

[0093] The optical fiber fixing process P**2** is then performed similarly to the first embodiment.

[0094] Subsequently, the contacting process P**3** is performed similarly to the first embodiment. However, in the embodiment, the optical fiber fixing substrate **30** is disposed on the component installation substrate **10** in such a manner that the optical fiber fixing substrate **30** is sandwiched between the guides **51**.

[0095] FIG. **8** is a diagram of an alignment process according to the embodiment. In the first embodiment, the first alignment process P**4** and the second alignment process P**5** are performed. However, in the embodiment, the guides **51** are formed at correct positions. Thus, the second alignment process is unnecessary. Therefore, as illustrated in FIG. **8**, the alignment process is performed by moving the optical fiber fixing substrate **30** along the longitudinal direction of the optical fiber **40**. The specific method of the alignment process is similar to the first alignment process P**4** in the first embodiment.

[0096] Subsequently, the optical fiber fixing substrate **30** is fixed to the component installation substrate **10** similarly to the first embodiment. Thus, the optical device according to the embodiment is obtained.

[0097] In accordance with the manufacturing method for an optical device according to the embodiment, the optical fiber fixing substrate **30** is disposed on the component installation substrate **10**, and this performs alignment of the direction perpendicular to the longitudinal direction of the optical fiber, in the direction in parallel with the contact surface of the component installation substrate **10** with the optical fiber fixing substrate **30**. Therefore, in accordance with the manufacturing method for an optical device according to the embodiment, disposing of the optical fiber fixing substrate **30** on the component installation substrate **10**, performs alignment in two directions perpendicular to the longitudinal direction of the optical fiber. Consequently, in accordance with the manufacturing method for an optical device according to the embodiment, an optical device allowing a reduction in optical losses can be manufactured easier than in the manufacturing method for an optical device according to the first embodiment.

[0098] In the embodiment, the guides **51** are installed at locations at which the opposite side surfaces of the optical fiber fixing substrate **30** are sandwiched. However, the locations of the guides **51** are not limited to these locations. For example, a configuration may be possible in which uniform grooves are formed on the surface **30***s* of the optical fiber fixing substrate **30**, the grooves extending in the direction in parallel with the longitudinal direction of the optical fiber **40**, and guides in shapes and at locations fit into the grooves are provided on the surface **12***s* of the optical fiber disposition area **12**.

[0099] The guides **51** may be provided so as to control the motion of the optical fiber fixing substrate **30** in the direction along the longitudinal direction of the optical fiber **40**.

[0100] The guides **51** may be provided by a thin film process different from the optical component installation process P1. The guides **51** may be formed of different members as the guides **51** are not formed of thin films.

Third Embodiment

[0101] Next, referring to FIG. **10**, a third embodiment of the present invention will be described in detail. Components the same as or equivalent to ones in the first embodiment are designated the same reference numerals and signs, and the overlapping description is omitted unless otherwise specified.

[0102] FIG. **10** is a diagram in which the component installation substrate **10** is being contacted with the optical fiber fixing substrate **30** in the embodiment. As illustrated in FIG. **10**, the component installation substrate **10** according to the embodiment is different from the component installation substrate **10** according to the first embodiment in that a pair of alignment marks **52** is provided on the surface **12***s* of the optical fiber disposition area **12**.

[0103] The alignment marks **52** are preferably provided in advance on a substrate to be the component installation substrate **10**. Relative to the positions of the alignment marks, the optical component installation process P**1** is performed similarly to the first embodiment. Thus, the positional relationship between the alignment marks **52** and the end portion **25** of the optical component **23** can be grasped.

[0104] The optical fiber fixing process P**2** is then performed similarly to the first embodiment.

[0105] Subsequently, the contacting process P**3** is performed. In the contacting process in the embodiment, the position of the optical fiber fixing substrate **30** is determined based on the alignment marks **52**, and the optical fiber fixing substrate **30** is disposed on the component installation substrate **10**. In the case in which the relationship between the positions of the alignment marks **52** and the position of the end portion **25** of the optical component **23** can be grasped as described above, the optical fiber fixing substrate **30** can be disposed at an appropriate position. Thus, the first alignment process P**4** and the second alignment process P**5** of the first embodiment can be omitted. However, in the case in which the position of the end portion **45** of the optical fiber **40** in the optical fiber fixing substrate **30** has variability in the optical fiber fixing process P**2**, the first alignment process P**4** is preferably performed.

[0106] Subsequently, the optical fiber fixing substrate **30** is fixed to the component installation substrate **10** similarly to the first embodiment. Thus, the optical device according to the embodiment is obtained.

Fourth Embodiment

[0107] Next, referring to FIG. **11**, a fourth embodiment of the present invention will be described in detail. Components the same as or equivalent to ones in the first embodiment are designated the same reference numerals and signs, and the overlapping description is omitted unless otherwise specified.

[0108] FIG. **11** is a diagram of an optical device according to the embodiment similarly viewed as in FIG. **3**. As illustrated in FIG. **11**, the optical device **1** according to the embodiment is different from the optical device **1** according to the first embodiment in that the optical fiber **40** has a pair of stress applying parts **43** sandwiching the core **41**. In other words, the optical fiber **40** according to the embodiment is a polarization maintaining and absorption reducing fiber (PANDA fiber), which is one kind of polarization maintaining optical fibers. The stress applying parts **43** are portions to apply stress to the core in manufacturing the optical fiber **40**. The stress applying parts **43** have a diameter greater than the diameter of the core, for example, and are provided at locations a certain distance apart from the core **41**. These stress applying parts **43** are provided. Thus, the optical fiber **40** can propagate a single-polarization light beam as the polarization axis is maintained. Therefore, a light beam entered to this optical fiber **40** is sometimes converted into a single-polarization light beam whose polarization axis is matched with the direction of the stress applying parts of the polarization maintaining optical fiber or whose polarization axis is orthogonal to the direction of the stress applying parts. Thus, in order to match the polarization direction of a light beam emitted from the waveguide **22** and entered to the optical fiber **40**, or emitted from the optical fiber **40** and entered to the waveguide **22**, it is important to adjust the position of the optical fiber **40** in the rotation axis direction.

[0109] In a manufacturing method for the optical device **1** according to the embodiment, the optical component installation process P**1** is performed similarly to the first embodiment. In the optical fiber fixing process P**2** of the embodiment, the rotation direction of the optical fiber **40** is adjusted relative to the center axis of the optical fiber **40** in such a manner that a desired direction is provided for the polarization direction of a light beam emitted from the waveguide **22** and entered to the optical fiber **40**, or emitted from the optical fiber **40** and entered to the waveguide **22**. This adjustment is performed while visually recognizing the end portion **45** of the optical fiber **40**, for example. For example, the end portion **45** of the optical fiber **40** can be visually recognized by shooting the end portion **45** using a camera, for example, through a monitor. The rotation direction of the optical fiber **40** is preferably adjusted prior to disposing the optical fiber **40** on the V-shaped groove **35**. The reason is that the adjustment is easily performed by visually recognizing the optical fiber **40**. However, the adjustment may be performed after the optical fiber **40** is disposed on the V-shaped groove **35**. Alternatively, the adjustment may be performed in disposing the optical fiber **40** on the V-shaped groove **35**.

[0110] Subsequently, the contacting process P**3**, the first alignment process P**4**, and the second alignment process P**5** are performed similarly to the first embodiment. Thus, the optical device according to the embodiment is obtained.

Fifth Embodiment

[0111] Next, referring to FIGS. **12** and **13**, a fifth embodiment of the present invention will be described in detail. Components the same as or equivalent to ones in the first embodiment are designated the same reference numerals and signs, and the overlapping description is omitted unless otherwise specified.

[0112] FIG. **12** is a diagram of an optical device according to the embodiment similarly viewed as in FIG. **3**. FIG. **13** is a diagram of the optical device according to the embodiment similarly viewed as in FIG. **4**. As illustrated in FIG. **12**, the optical device **1** according to the embodiment is a multicore optical fiber in which the optical fiber **40** includes a plurality of cores **41**. As illustrated in FIG. **13**, the optical device **1** according to the embodiment is different from the optical device **1** according to the first embodiment in that a plurality of waveguides **22** is formed on the optical layer **20** on the component installation substrate **10**. In the optical fiber **40** according to the embodiment, the plurality of cores **41** is linearly arranged. Thus, the number of the plurality of waveguides **22** formed on the optical layer **20** on the component installation substrate **10** is the same as the number of the plurality of cores **41** of the optical fiber **40**, and the plurality of waveguides **22** is spaced with the same gap. In this optical device **1**, it is important that light beams emitted from the waveguides **22** be individually entered to the cores **41** of the optical fiber **40**, or light beams emitted from the cores **41** of the optical fiber **40** be individually entered to the waveguides **22**.

[0113] The optical component installation process P**1** in a manufacturing method for the optical device **1** according to the embodiment is different from the optical component installation process P**1** in the first embodiment in that the plurality of waveguides **22** is formed. In this process of the embodiment, the waveguides **22** are formed in such a manner that the number of the gaps of the plurality of waveguides **22** is the same as the number of the plurality of cores **41** of the optical fiber **40** spaced with the same gap as described above.

[0114] In the optical fiber fixing process P**2** of the embodiment, after the contacting process P**3** is performed, the rotation direction of the optical fiber **40** is adjusted relative to the center axis of the optical fiber **40** in such a manner that the array direction of the plurality of cores of the optical fiber **40** is the same as the array direction of the plurality of waveguides **22** of the optical layer **20**. This adjustment can be performed similarly to the adjustment in the fourth embodiment. Also in the embodiment, adjustment in the rotation direction of the optical fiber **40** is preferably performed prior to disposing the optical fiber **40** on the V-shaped groove **35**. However, the adjustment may be performed after the optical fiber **40** is disposed on the V-shaped groove **35**. Alternatively, the adjustment may be performed in disposing the optical fiber **40** on the V-shaped groove **35**.

[0115] Subsequently, the contacting process P**3**, the first alignment process P**4**, and the second alignment process P**5** are performed similarly to the first embodiment. Thus, the optical device according to the embodiment is obtained.

[0116] As described above, the present invention is described as the first to the fifth embodiments are taken as examples. However, the present invention is not limited to these embodiments.

[0117] For example, in the foregoing embodiments, the optical component **23** includes the optical element layer **21** and the waveguide **22**. However, the present invention is not limited to this configuration. For example, the optical component may include only the waveguide. Alternatively, the optical component may include only an optical element layer having an end portion through which at least a light beam is entered or emitted.

[0118] As described above, in accordance with a manufacturing method for an optical device according to the present invention, an optical device allowing a reduction in optical losses can be easily manufactured, which can be used in the fields of optical communication devices, optical measurement devices, and other devices.

1. A manufacturing method for an optical device, the method comprising:

an optical component installation process in which an optical component is installed on one face of a component installation substrate using a thin film process, the optical component having an end portion to be optically coupled to an optical fiber;

a process in which a groove is formed at a position at which the optical fiber has to be disposed when the component installation substrate is seen in a planar view;

a process in which a groove is formed, the groove crossing the groove formed at the position at which the optical fiber has to be disposed on the component installation substrate, the groove being deeper than the groove formed at the position at which the optical fiber has to be disposed, the end portion of the optical component being exposed from the groove crossing the groove formed at the position at which the optical fiber has to be disposed;

an optical fiber fixing process in which a V-shaped groove is formed on one face side of an optical fiber fixing substrate and the optical fiber is fixed to the V-shaped groove; and

a contacting process in which a part of a surface of the component installation substrate on which the optical component is provided is contacted with at least a part of a surface of the optical fiber fixing substrate on which the optical fiber is fixed, wherein

the groove formed at the position at which the optical fiber has to be disposed on the component installation substrate has a size in which in contacting the component installation substrate with the optical fiber fixing substrate, the optical fiber is not contacted with the component installation substrate.

2. The manufacturing method for an optical device according to claim **1**, wherein

on the component installation substrate, a guide is formed to control a motion of the optical fiber fixing substrate in a direction perpendicular to a longitudinal direction of the optical fiber, in a direction in parallel with a contact surface of the optical fiber fixing substrate with the component installation substrate.

3. The manufacturing method for an optical device according to claim **2**, wherein

the guide does not control the motion of the optical fiber fixing substrate along the longitudinal direction of the optical fiber.

4. The manufacturing method for an optical device according to claim **2**, wherein

the guide is formed in a process of providing the optical component.

5. The manufacturing method for an optical device according to claim **1**, wherein:

the component installation substrate is provided with an alignment mark; and

based on the alignment mark, a relative positional relationship between the component installation substrate and the optical fiber fixing substrate is defined.

6. The manufacturing method for an optical device according to claim **1**, wherein:

both of the end portion of the optical component and the end portion of the optical fiber are visually recognizable; and

an alignment process is further provided in which after the contacting process, the end portion of the optical component and the end portion of the optical fiber are visually recognized, and relative positions in the direction perpendicular to the longitudinal direction of the optical fiber are adjusted in the direction in parallel with the contact surface of the component installation substrate with the optical fiber fixing substrate.

7. The manufacturing method for an optical device according to claim **6**, wherein

the optical fiber is fixed in a state in which the end portion of the optical fiber protrudes from the optical fiber fixing substrate

8. The manufacturing method for an optical device according to claim **6**, wherein:

the optical fiber fixing substrate is of optical transparency; and

the end portion of the optical fiber is visually recognized through the optical fiber fixing substrate.

9. The manufacturing method for an optical device according to claim **1**, wherein:

the end portion of the optical component is visually recognizable;

the optical fiber fixing substrate is of optical transparency; and

an alignment process is further provided in which after the contacting process, the end portion of the optical component and the center line of the V-shaped groove are visually recognized, and relative positions are adjusted in the direction parallel with the contact surface of the component installation substrate with the optical fiber fixing substrate and perpendicular to the longitudinal direction of the optical fiber.

10. The manufacturing method for an optical device according to claim **1**, wherein

in the optical fiber fixing process, a rotation direction of the optical fiber is adjusted relative to the center axis of the optical fiber.

11. The manufacturing method for an optical device according to claim **1**, wherein

the optical fiber is a polarization maintaining optical fiber or a multicore optical fiber.

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